23.4 Gibbs free energy change

Name: _____ Class: _____ Date: _____ **Total: 11 marks**

KEY WORDS gibbs free energy change • gibbs free energy • feasibility • entropy • entropy change

Objective

Build the skills to answer exam questions on **Gibbs free energy change** – using $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ to judge **feasibility** .

You must be able to:

- state and use the Gibbs equation
- use the sign of ΔG to decide whether a reaction is feasible
- predict the effect of temperature on feasibility

1 Key knowledge and worked examples

■ The Gibbs equation

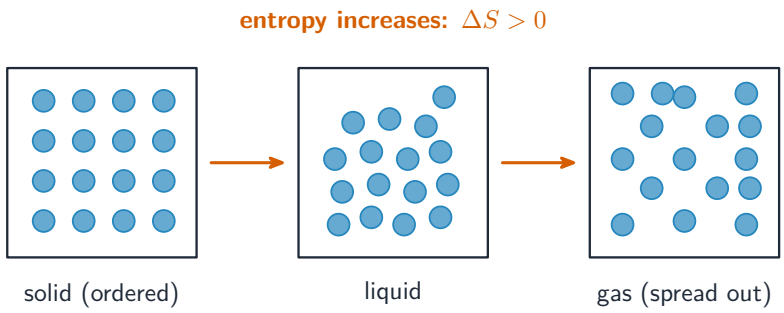
$$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$$

A reaction is **feasible** when $\Delta G \leq 0$.

	ΔS **positive**	ΔS **negative**
ΔH **neg.**	feasible at **all** temperatures	feasible only at **low** temperature
ΔH **pos.**	feasible only at **high** temperature	**never** feasible

$\Delta G = \Delta H - T\Delta S$; **feasible when** $\Delta G \leq 0$

Feasibility depends on temperature: a $+\Delta S$ reaction becomes feasible above a certain T (where $T\Delta S$ outweighs ΔH)



Gibbs combines enthalpy and entropy changes

Watch the units: ΔH is in kJ mol^{-1} but ΔS is in J K^{-1} mol^{-1} – divide ΔS by 1000 (or multiply ΔH by 1000) before subtracting.

Example. ΔH = +178 kJ mol^{-1}, ΔS = +160 J K^{-1} mol^{-1}. At 298 K: $\Delta G = 178 - 298(0.160) = 178 - 47.7 = +130$ kJ mol^{-1} (not feasible). It becomes feasible above $T = \Delta H/\Delta S = 178/0.160 = 1113$ K.

2 Practice

2.1 State the Gibbs equation. [1]

2.2 State the condition on ΔG for a reaction to be feasible. [1]

3 Exam-style questions

3.1 A reaction has ΔH negative and ΔS positive. It is: [1]

- ☐ **A** feasible at all temperatures
- **B** feasible only at high temperature
- **C** feasible only at low temperature
- **D** never feasible

3.2 In the Gibbs equation, the temperature T must be in: [1]

- ☐ **A** °C
- **B** kelvin
- **C** joules
- **D** kJ

3.3 A reaction has $\Delta H = +120$ kJ mol^{-1} and $\Delta S = +200$ J K^{-1}mol^{-1}.

(a) Calculate ΔG at 298 K and state whether the reaction is feasible. [3]

(b) Calculate the minimum temperature at which the reaction becomes feasible. [2]

3.4 Explain why an endothermic reaction with a positive entropy change becomes feasible only above a certain temperature. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$

2.2

- $\Delta G \leq 0$ (negative or zero)

3.1 A

- With $-\Delta$H and $+\Delta$S, ΔG is negative at all temperatures

3.2 B

- Temperature must be in kelvin

3.3

(a)

- $\Delta G = 120 - 298(0.200) = 120 - 59.6 = +60.4$ kJ mol^{-1}; not feasible (positive ΔG)

(b)

- feasible when $\Delta G = 0$: $T = \Delta H/\Delta S = 120/0.200 = 600$ K

3.4

- at low T the $T\Delta S$ term is small, so $\Delta G = \Delta H - T\Delta S$ stays positive; raising T increases $T\Delta S$ until it exceeds ΔH, making ΔG negative and the reaction feasible